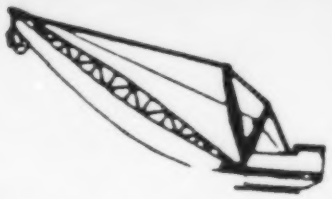

NB COAL LIMITED

A Subsidiary Company Of
NEW BRUNSWICK POWER
ÉNERGIE NOVEAU-BRUNSWICK

Optimization of Dragline Performance Through Computer Control

Phase III, Final Report

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OPTIMIZATION OF DRAGLINE PERFORMANCE THROUGH COMPUTER CONTROL PHASE III

FINAL REPORT

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1. EXECUTIVE SUMMARY

The purpose of Phase III was to install the equipment and software necessary to enable the collection of dragline safety and operational parameters in preparation for the performance of Phase IV. We believe we have fulfilled these requirements, including the January 1991 amendment to the Statement of Work which included the development of preliminary software for the office and supervisor's system.

All possible equipment and sensor installations have occurred and software has been written and tested in preparation for Phase IV. That phase will produce offline and realtime advisory, analytical, archiving and reporting capabilities.

The system has demonstrated control of the lubrication system. It is now operating in the control mode and continuously displaying lubrication parameters on a screen at the dragline. Other software components for implementing Phase IV are well advanced and preliminary versions are due for integration.

In Phase I the Stressalert was installed to monitor stresses in the backleg kneeplate of the dragline. Groundwork observations of baseline data collected with a chart recorder have been compared with Stressalert data. There was an excellent correlation between the two data collection methods. The dig cycle key points were marked on the chart recordings. These demonstrated that the high stress points of a cycle were at the moment a load is dumped. This suggests that stresses may be lowered by releasing the bucket load more gradually.

2.0 INTRODUCTION

The purpose of phase III was to install the equipment and software necessary to enable the collection of dragline safety and operational parameters in preparation for the realtime and offline analytical tools to be developed in Phase IV. Equipment and sensors have been installed and software has been written and tested in preparation for Phase IV.

Initially installations were progressing at a slower pace than anticipated. More manpower was allocated to increase and improve the interaction with NBCOAL operations personnel. Subsequent installations progressed more satisfactorily.

3.0 TECHNICAL DISCUSSION

There are four aspects to the overall project that were to be completed by the end of Phase III.

1. Installation of equipment and sensors.

2. Development of lubrication monitor and control software.

3. Observation and gathering of baseline data for use in the expert systems to be developed in Phase IV.

4. Preliminary development of office system and supervisor's system software.

3.1 Installation of Equipment and Sensors

All sensors necessary to the development of the expert system have been installed. Virtually all other sensors have also been installed. The exception is two thermocouple sensors for two of the twenty motor-generator sets. These were unable to be installed because of interference problems that were discovered during the installation procedure for the other motor-generator sets. NBCOAL will be removing the covers, probably during the annual shutdown, to locate the source of this anomaly, hopefully to remedy it.

Appendix A lists the sensors, with their locations, installed on the Marion 8200. The list excludes the thirteen strain gauges installed on the back kneeplate in Phase I.

The swing angle, flow sensors, and step sensor are discussed in more detail here:

The swing angle sensor consists of a toothed belt on the shaft originally used to graph swing angle by a mechanical chart recorder. The belt in turn drives another sprocket which operates an angle sensor. Unfortunately the shaft wobbled beyond the ability of the belt to withstand. The belt broke after a few days. The gauge mounting was redesigned to be on

a teflon slide with spring tensioning. This provided the flexibility to tolerate the shaft wobble.

After the first flow sensor was installed, it was evident that its flow capabilities were inadequate. Further examination revealed that the throughput of the lubrication pumps was greater than originally believed. The four flow sensors were replaced by units with ten times the capacity. The new size operates with acceptable pressure drop, typically about 30 psi.

The design of the flow sensor installation improved significantly after the first one was installed. It was always recognised that we had to be able to bypass flow around the sensors. This was achieved for the first sensor by using a loop bypass and three valves to isolate the sensor if required. The much simpler system used for the subsequent units employed quick disconnect fittings on the existing flexible hose lines. The sensors are installed inline. When desired, they can be easily removed and the hose reconnected. No additional valves are used.

The step sensor was installed to count the steps during Propel mode on the dragline. The current practise is for the dragline operator to count the steps and enter the number on his log. We installed an ultrasonic position indicator that notes whenever the left foot link is raised or lowered. It is mounted high on the wall, away from the link itself. This puts it out of the way of personnel working on the walking link mechanism.

3.1.1 Long Term Operation

The Stressalert has been actively monitoring and recording kneeplate stresses for two years. Its long term behaviour will be reported here. It has reliably given operators overstress information and has identified the high stress operating conditions. It operated with only a few isolated cases of false alarms. We believe the sources of these have all been identified and have taken steps to prevent their re-occurrence. These false readings always generated values that were physically impossible, thus immediately and correctly indicating a problem with the sensing equipment.

There were two cases of stresses drifting to an overload condition. These were traced to wires that had become loose. Tightening and securing the wires eliminated the problem.

There was one case which had symptoms similar to the above except the problem completely resolved itself with no outside efforts. It is believed that the incident was due to a combination of unusual weather conditions in conjunction with the vertical conduit leading into the Stressalert enclosure. The conduit had been provisionally blocked with paper towels to block any drafts. Removing the blockage let about twenty dead flies fall out. There was a noticeable draft from the metal conduit. The incident happened after the weather had warmed dramatically after experiencing the coldest night of the year. We believe that moisture within the conduit had frozen then thawed. The water soaked through the paper towels and then dripped onto the wire terminals below. The water caused an electrical short circuit which eventually evaporated.

As a precaution, the conduit was sealed more securely. A drip path was established at the open end. Any remaining drips would be directed to fall away from the terminals. This eliminated any re-occurrence of this type of false alarm.

Several times a single overstress event happened where all the stresses appeared to swerve to one side. This is not physically possible as some gauges must be in tension while others are in compression. Further examination revealed that if the input AC power to the Stressalert dipped significantly ("brownout" condition), the gauges would exhibit the same behaviour. We found that the strain gauge signal conditioning modules were affected by brownouts; the other computer circuitry is protected.

An Uninterruptable Power Supply has been purchased and will be installed. Then voltage drops will be prevented from reaching the stress monitoring equipment. The data acquisition equipment installed in the large rack is already protected by an Uninterruptable Power Supply.

3.2 Lubrication Control/Monitor

The computer controlled lubrication system was installed and underwent careful stepwise testing of each constituent. Operation was confirmed for the different dragline operating modes. Different failure modes were simulated to ensure that lubrication control would automatically and safely revert to the former electromechanical timer control system.

The operation of all sensors attached to the system were verified under different conditions of temperature, humidity and dragline operating modes.

3.3 Baseline Testing and Observation

To further characterise the Stressalert data and to gain further insights into parameters relevant for the realtime advisory system of Phase IV, baseline data was gathered using a chart recorder. This was attached to the strain gauges that normally go to the Stressalert. The parts of a cycle were identified on the recordings. An analysis of the results is contained in Appendix B. The results closely match the Stressalert records.

It became clear that the maximum stress normally occurred as the loaded bucket begins to dump. Discussions with operators confirmed this to be the case when they usually got an overstress alarm. This was a bit surprising since we had presupposed that the maximum stress would probably occur when the operator started to swing while "digging off the top". The operators stated it tended to happen only when they were digging off the top and trying to reach the top of the spill pile without premature spillage. The problem was aggravated when the dragline was not perfectly level, but tilted slightly downward when facing the spill pile. This meant the bucket had to be hoisted further out and up.

The charts also show an oscillation that is of higher frequency when hauling a loaded bucket. Direct observation of the dragline structure confirmed that the boom cables also exhibited the same frequency behaviour.

All this led to our current working theory of the cause of the peak stress location. We believe the dragline boom and its cables act like a large musical instrument. The bucket load and pull of the drag cables stress the hoist cables so that they, with the boom structure, have a particular vibration frequency. Releasing the drag pull and dropping the load reduces tension on the hoist cables, lowering their vibration frequency. Usually the bucket load is dumped rapidly. This is similar to plucking a guitar. The reaction sets up an initial 'pluck' amplitude that causes a stress spike.

We want to explore this theory further by seeing how a slower bucket dump will effect the stress profile. We also plan to explore the correlation of oscillation frequency and amplitude with dragline cycle.

3.4 Operator's Console

Work has progressed on the development of a display for realtime use by dragline operators. We have also observed the operating habits of different operators and noted their behaviour under different operating conditions.

It became apparent that an adjustable console mount is required to adapt to different operators and operating conditions. A Termiflex graphics screen will be used. This has a touch panel beneath the screen for use by the operator.

We are currently investigating the display of simple bar graphs that can be observed with a glance. One method would be to use a "fuzzy" combination of dragline cycle location and boom loads to anticipate upcoming loads, and to suggest the operator's "aggressiveness" of control use. This might be presented on two of the bar graphs. Two other graphs would correspond to actual system loads.

Any system alarms are displayable on the operator's console. He communicates with the console by using the touch panel to select menu items. It is possible to enter text messages by selecting letters from an alphabet menu.

It is important to balance quickness of operator understanding, preferably by peripheral vision, relevance of the data presented, and the physical limitations of the operator's display both in content and speed of response.

3.5 Office and Supervisor's Systems

Both office and supervisor system software have been designed. They have been designed to be simple to use with minimal training. Preliminary versions have been tested using dummy data.

3.6 Exposure

To obtain third-party feedback of our work at NBCOAL an oral presentation was given at the COSMET meeting at Moncton, NB in July. This was followed by papers and presentations given at the International Symposium on Mine Planning and Equipment Selection in Surface Mining at Calgary in November. Copies of these papers are in Appendix C and D.

Considerable positive interest was expressed by the attendees of these conferences. Another presentation is planned for May 1 at the 93rd Annual General Meeting of CIM in Vancouver.

4.0 CONCLUSIONS

The requirements of Phase III of this contract have been fulfilled. At this point in the overall project, we are gathering data with the equipment installed in Phases I through III.

Preliminary data analyses have already indicated one area where simply slower bucket dumping might reduce peak stresses. This has a direct impact on the long term life of boom, bucket and cables.

We have set up the framework for long term data acquisition and lubrication control. We are poised to begin Phase IV where a realtime advisory system is established for the operator. The supervisor and office will receive trend analytical tools, reporting capabilities and archival of operational and safety data.

APPENDICES

APPENDIX A.
SENSORS INSTALLED ON MARION 8200

Key:	Name	Description:
Sensors:		
DRPO	Drag Rope Payout Sensor	Micron 36-509-678-1962 Pot.
HRPO	Hoist Rope Payout Sensor	Micron 36-509-678-1962 Pot.
FS-1	Foot Sensor #1	Pulsotronic M30 Ultrasonic
LF-1	Lubricant Flow Sensor #1	ZHM 02 bi-directional gear flow
LF-2	Lubricant Flow Sensor #2	ZHM 02 bi-directional gear flow
LF-3	Lubricant Flow Sensor #3	ZHM 02 bi-directional gear flow
LF-4	Lubricant Flow Sensor #4	ZHM 02 bi-directional gear flow
LL-1	Lubricant Tank Level Sensor #1	Hydrostatic Pressure Sensor
LL-2	Lubricant Tank Level Sensor #2	Hydrostatic Pressure Sensor
LL-3	Lubricant Tank Level Sensor #3	Hydrostatic Pressure Sensor
LL-4	Ambient Pressure Sensor #4	Hydrostatic Pressure Sensor
SA-1	Swing Angle Sensor #1	Maurey 112-P16-202 2k 20%
Strain Gauges:		
SG-1	Strain Gauge #1 - Boompoint Left Rear	Half-Bridge - 350 ohm
SG-2	Strain Gauge #2 - Boompoint Left Middle	Half-Bridge - 350 ohm
SG-3	Strain Gauge #3 - Boompoint Left Front	Half-Bridge - 350 ohm
SG-4	Strain Gauge #4 - Boompoint Right Rear	Half-Bridge - 350 ohm
SG-5	Strain Gauge #5 - Boompoint Right Middle	Half-Bridge - 350 ohm
SG-6	Strain Gauge #6 - Boompoint Right Front	Half-Bridge - 350 ohm
SG-7	Strain Gauge #7 - Fairlead Right Bottom	Half-Bridge - 350 ohm
SG-8	Strain Gauge #8 - Fairlead Right Top	Half-Bridge - 350 ohm
Thermocouples:		
AT-1	Ambient Temperature #1	Omega KOSS-186-12
DD-1	Drag Drum - Left - #1	Omega NB1-CASS-186-9-9BSL
DD-2	Drag Drum - Right - #2	Omega NB1-CASS-186-9-9BSL
DT-1I	Drag Transmission #1 - Intermediate Bearing	Omega BT-090K-5/6.5-60-1
DT-1E	Drag Transmission #1 - Endcap Bearing	Omega BT-090-3.5-60-1
DT-2I	Drag Transmission #2 - Intermediate Bearing	Omega BT-090K-5/6.5-60-1
DT-2E	Drag Transmission #2 - Endcap Bearing	Omega BT-090-3.5-60-1
DT-3I	Drag Transmission #3 - Intermediate Bearing	Omega BT-090K-5/6.5-60-1
DT-3E	Drag Transmission #3 - Endcap Bearing	Omega BT-090-3.5-60-1

DT-4I	Drag Transmission #4 - Intermediate Bearing	Omega BT-090K-5/6.5-60-1
DT-4E	Drag Transmission #4 - Endcap Bearing	Omega BT-090-3.5-60-1
HD-3	Hoist Drum - Left - #3	Omega NB1-CASS-18G-9-9BSL
HD-4	Hoist Drum - Right - #4	Omega NB1-CASS-18G-9-9BSL
HT-1I	Hoist Transmission #1 - Intermediate Bearing	Omega BT-090K-5/6.5-60-1
HT-1E	Hoist Transmission #1 - Endcap Bearing	Omega BT-090-3.5-60-1
HT-2I	Hoist Transmission #2 - Intermediate Bearing	Omega BT-090K-5/6.5-60-1
HT-2E	Hoist Transmission #2 - Endcap Bearing	Omega BT-090-3.5-60-1
HT-3I	Hoist Transmission #3 - Intermediate Bearing	Omega BT-090K-5/6.5-60-1
HT-3E	Hoist Transmission #3 - Endcap Bearing	Omega BT-090-3.5-60-1
HT-4I	Hoist Transmission #4 - Intermediate Bearing	Omega BT-090K-5/6.5-60-1
HT-4E	Hoist Transmission #4 - Endcap Bearing	Omega BT-090-3.5-60-1
HT-5I	Hoist Transmission #5 - Intermediate Bearing	Omega BT-090K-5/6.5-60-1
HT-5E	Hoist Transmission #5 - Endcap Bearing	Omega BT-090-3.5-60-1
MG-1	M-G Set Pedestal Bearing #1	Omega KQSS-18G-12
MG-2	M-G Set Pedestal Bearing #2	Omega KQSS-18G-12
MG-3	M-G Set Pedestal Bearing #3	Omega KQSS-18G-12
MG-4	M-G Set Pedestal Bearing #4	Omega KQSS-18G-12
MG-5	M-G Set Pedestal Bearing #5	Omega KQSS-18G-12
MG-6	M-G Set Pedestal Bearing #6	Omega KQSS-18G-12
MG-7	M-G Set Pedestal Bearing #7	Omega KQSS-18G-12
MG-8	M-G Set Pedestal Bearing #8	Omega KQSS-18G-12
MG-9	M-G Set Pedestal Bearing #9	Omega KQSS-18G-12
MG-10	M-G Set Pedestal Bearing #10	Omega KQSS-18G-12
MG-11	M-G Set Pedestal Bearing #11	Omega KQSS-18G-12
MG-12	M-G Set Pedestal Bearing #12	Omega KQSS-18G-12
MG-13	M-G Set Pedestal Bearing #13	Omega KQSS-18G-12
MG-14	M-G Set Pedestal Bearing #14	Omega KQSS-18G-12
MG-15	M-G Set Pedestal Bearing #15	Omega KQSS-18G-12
MG-16	M-G Set Pedestal Bearing #16	Omega KQSS-18G-12
MG-17	M-G Set Pedestal Bearing #17	Omega KQSS-18G-12
MG-18	M-G Set Pedestal Bearing #18	Omega KQSS-18G-12
MG-19	M-G Set Pedestal Bearing #19	Omega KQSS-18G-12
MG-20	M-G Set Pedestal Bearing #20	Omega KQSS-18G-12
SM-1U	Swing Motor #1 - Upper Bearing	Omega BT-090K-3.5-60-1
SM-1I	Swing Motor #1 - Intermediate Bearing	Omega NB1-CASS-18G-7-7BSL
SM-1L	Swing Motor #1 - Lower Bearing	Omega NB1-CASS-18G-7-7BSL
SM-2U	Swing Motor #2 - Upper Bearing	Omega BT-090K-3.5-60-1
SM-2I	Swing Motor #2 - Intermediate Bearing	Omega NB1-CASS-18G-7-7BSL
SM-2L	Swing Motor #2 - Lower Bearing	Omega NB1-CASS-18G-7-7BSL
SM-3U	Swing Motor #3 - Upper Bearing	Omega BT-090K-3.5-60-1
SM-3I	Swing Motor #3 - Intermediate Bearing	Omega NB1-CASS-18G-7-7BSL

SM-3L	Swing Motor #3 - Lower Bearing	Omega NB1-CASS-18G-7-7BSL
SM-4U	Swing Motor #4 - Upper Bearing	Omega BT-090K-3.5-60-1
SM-4I	Swing Motor #4 - Intermediate Bearing	Omega NB1-CASS-18G-7-7BSL
SM-4L	Swing Motor #4 - Lower Bearing	Omega NB1-CASS-18G-7-7BSL
SM-5U	Swing Motor #5 - Upper Bearing	Omega BT-090K-3.5-60-1
SM-5I	Swing Motor #5 - Intermediate Bearing	Omega NB1-CASS-18G-7-7BSL
SM-5L	Swing Motor #5 - Lower Bearing	Omega NB1-CASS-18G-7-7BSL

Junction Boxes:

20	M-G Set Thermocouple	Appleton GRC-50
18	Transmission Thermocouple	Appleton GRC-50
5	Swing Machinery Upper Bearing Thermocouple	Appleton GRC-50
1	Ambient Temperature Thermocouple	Appleton GRC-50
1	Ultrasonic Foot Sensor	Crouse Hinds GRF119
2	Rope Payout Transducer	Crouse Hinds GRF119
2	Boompoint Strain Gauges	Bell N080804CH
1	Boompoint Strain Gauges	Bell N060604CH
1	Fairlead Strain Gauges	Appleton
1	Lubrication System	
1	M-G Set Thermocouple	Hammond 1418JB7
1	Transmission Thermocouple	Hammond 1418JB7
2	Swing Machinery Thermocouple	Hammond 1414I

APPENDIX B.
STRAIN GAUGE DATA INTERPRETATION

3/20/91
../8

NOTE TO: FREDERICK A. LEIDEMER
ELECTRONICS DEPARTMENT
RPC
FREDERICTON, NEW BRUNSWICK, CANADA

DATE: 20 MARCH 1991

FROM: JEFF DESLANDES
PRINCIPAL RESEARCH ENGINEER
BHP RESEARCH - MELBOURNE LABORATORIES

COPY TO : LEE DANISCH, RAY ST-LAURENT,
JOHN OLIVE, BRIAN BELL (RPC)

SUBJECT: DATA FROM MARION 8200 STRAIN GAUGES

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1. INTRODUCTION

STRAIN GAUGE DATA FOR THE TRI-STRUCTURE OF THE MARION 8200 DRAGLINE AT N.B. COAL AT MINTO, NEW BRUNSWICK WAS COLLECTED BY RPC PERSONNEL ON 27 AND 28 FEBRUARY 1991. THIS NOTE DESCRIBES AN INTERPRETATION OF THIS DATA WITH RESPECT TO DRAGLINE OPERATIONS.

2. PRODUCTION PARAMETERS

THE FOLLOWING DRAGLINE PRODUCTION STATISTICS CAN BE DERIVED FROM THE SAMPLE DATA:

CYCLE #	BUCKET FILL TIME(s)	SWING TO DUMP(s)	DUMP TIME (s)	RETURN SWING TIME(s)	CYCLE TIME (s)
11.51 A.M. 28 FEBRUARY 1991					
1	21.9	16.4	5.6	23.5	67.4
2	23.2	17.8	6.2	28.3	75.5
3	67.7	21.9	6.2	30.0	104.7
4	33.7	18.7	7.0	28.6	88.0
MEAN	35.4	18.7	6.3	27.3	88.9
12.27 P.M. 28 FEBRUARY 1991					
17	10.5	14.4	4.5	18.0	47.4
18	8.5	14.6	6.5	16.5	46.1
19	11.3	14.1	3.7	18.3	47.4
20	11.1	15.3	5.1	18.1	49.6
MEAN	10.4	14.6	5.0	17.7	47.6

THE OVERALL CYCLE TIME COMPARES WITH THE FIGURE OF 70 TO 80 SECONDS QUOTED BY N.B. COAL FOR THIS MACHINE. THE DIG TIME FOR CYCLE 3 WAS PARTICULARLY LONG.

3. STRAIN RECORDS

THE FOLLLOWING OBSERVATIONS CAN BE MADE FOR THE STRAIN TRACES SUPPLIED FOR STRAIN GAUGES # 1 TO 4 ON THE TRI-STRUCTURE:

- TRI-STRUCTURE STRAIN (AND STRESS) IS GENERALLY VERY LOW IN THE PROPEL MODE.

- STRAIN GAUGES # 2 & 4 ARE THE MOST ACTIVE, WITH GAUGE # 2 NEGATIVE OUTPUT (I.E. IN COMPRESSION) AND GAUGE # 4 POSITIVE OUTPUT (I.E. IN TENSION) (THIS AGREES WITH PREVIOUS STRESSALERT HISTORIES).

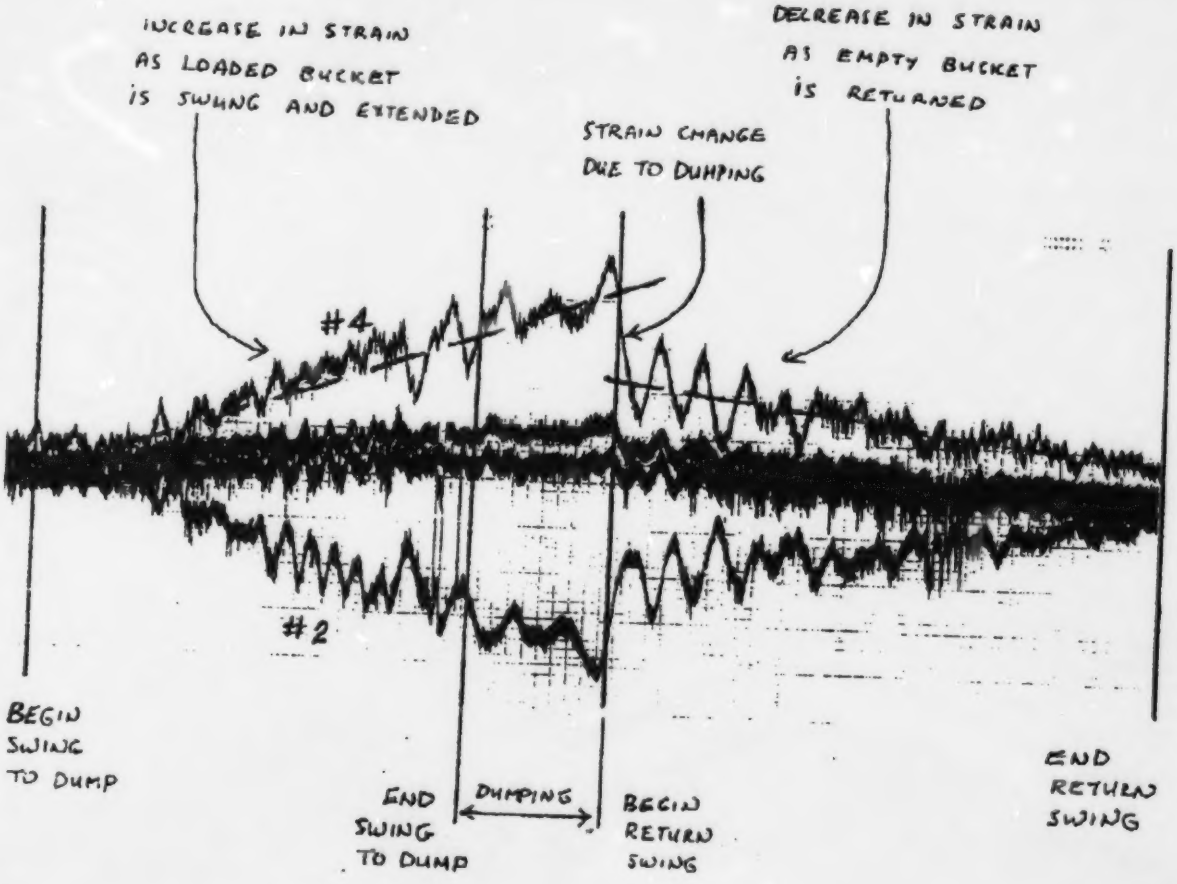
- TRI-STRUCTURE STRESS IS INSIGNIFICANT IN THE DIG MODE (PRESUMABLY AS THE DUMP ROPE IS SLACK, WITH THE DIG FORCE TAKEN BY THE FAIRLEAD).

- TRI-STRUCTURE STRESS INCREASES IN MAGNITUDE DURING THE SWING TO DUMP (AS THE LOADED BUCKET WHICH IS INITIALLY CLOSE TO THE BOOM AND THE FAIRLEAD, IS SWUNG AND RAISED TO THE END OF THE BOOM). REFER TO FIGURE 1 FOR DETAILS.

- THERE IS GENERALLY A SMALL REDUCTION IN TRI-STRUCTURE STRESS WHEN HOISTING STOPS (PRESUMABLY DUE TO THE RELEASE OF HOIST ROPE DYNAMIC LOAD). REFER TO FIGURE 2 FOR DETAILS.

- TRI-STRUCTURE STRESS IS GENERALLY HIGHEST IN MAGNITUDE NEAR TO, OR DURING DUMPING. DYNAMIC LOADING DUE TO JERKING OF THE DRAGLINE BUCKET WOULD SEEM TO BE IMPORTANT DURING DUMPING. AGAIN REFER TO FIGURE 2 FOR DETAILS.

- THE STRAIN RECORDS APPEAR TO CORRELATE VERY CLOSELY WITH PREVIOUS STRESSALERT STRESS RECORDS. FIGURE 3 SHOWS A COMPARISON OF CYCLE 17 WITH A PREVIOUS STRESSALERT RECORD. IT IS CLEAR THAT THE STRESSALARM CONDITIONS HAVE TYPICALLY BEEN OCCURRING IN THE VICINITY OF THE DUMP CYCLE.



STRAIN RECORD #17
28FEB91 12:27

FIG. 1: TYPICAL TRI-STRUCTURE STRAIN TRACE FOR ONE CYCLE.

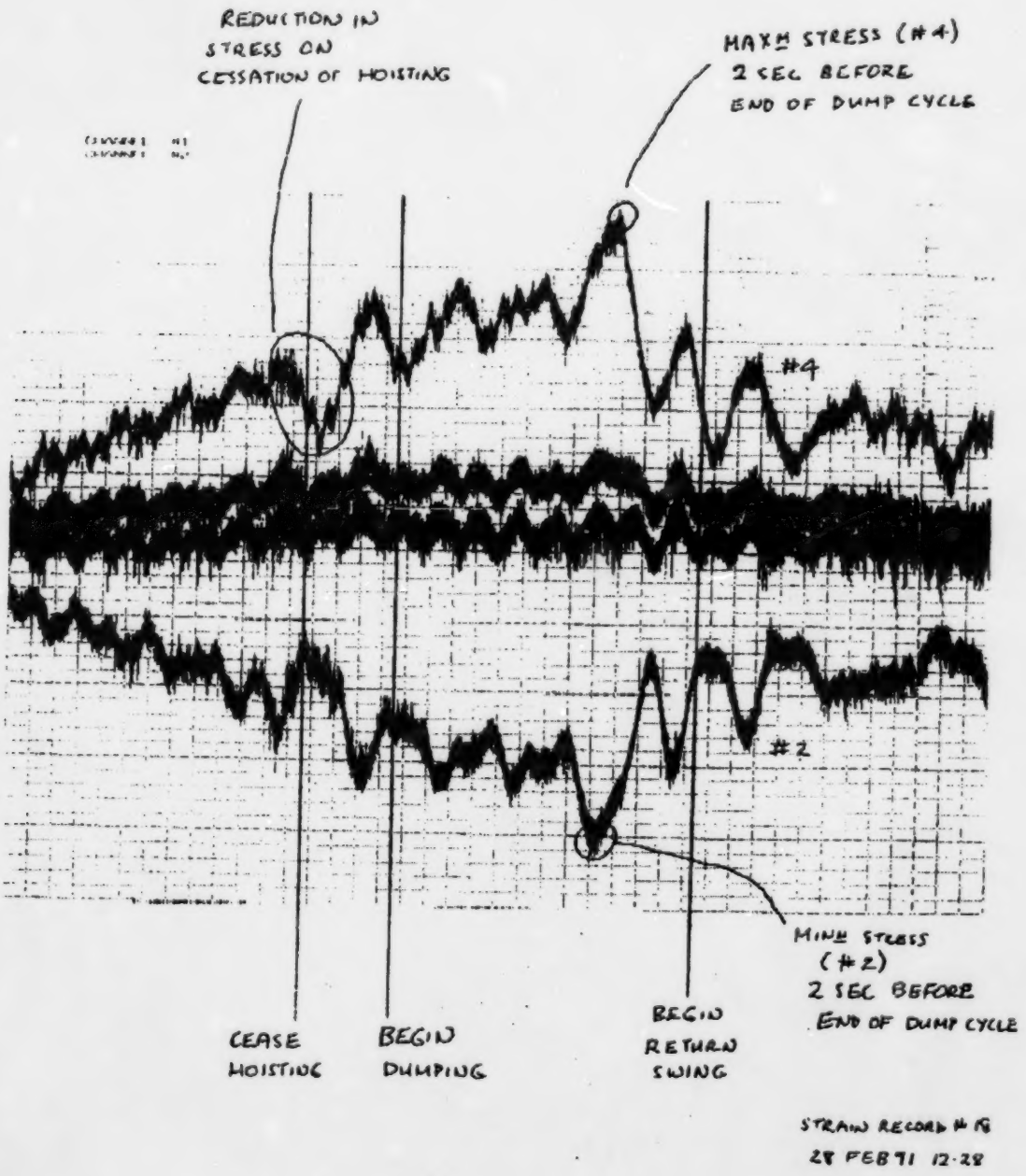
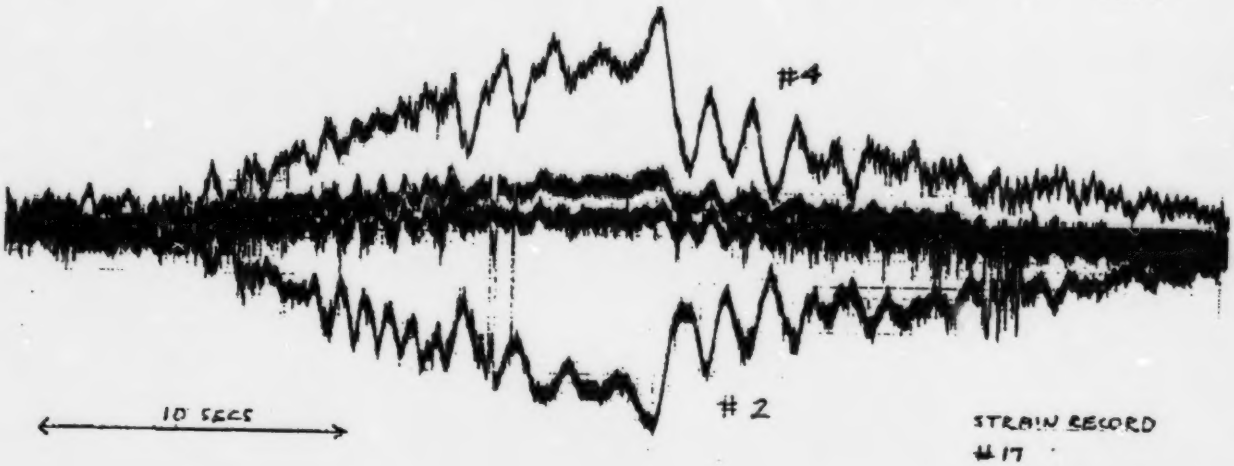

REDUCTION IN STRESS ON CESSATION OF HOISTING
MAXM STRESS (#4) 2 SEC BEFORE END OF DUMP CYCLE
#4
#2
MINM STRESS (#2) 2 SEC BEFORE END OF DUMP CYCLE
CEASE HOISTING
BEGIN DUMPING
BEGIN RETURN SWING
STRAIN RECORD # 16
28 FEB 91 12:28

FIG. 2: TYPICAL TRI-STRUCTURE STRAIN TRACE NEAR DUMPING PHASE.



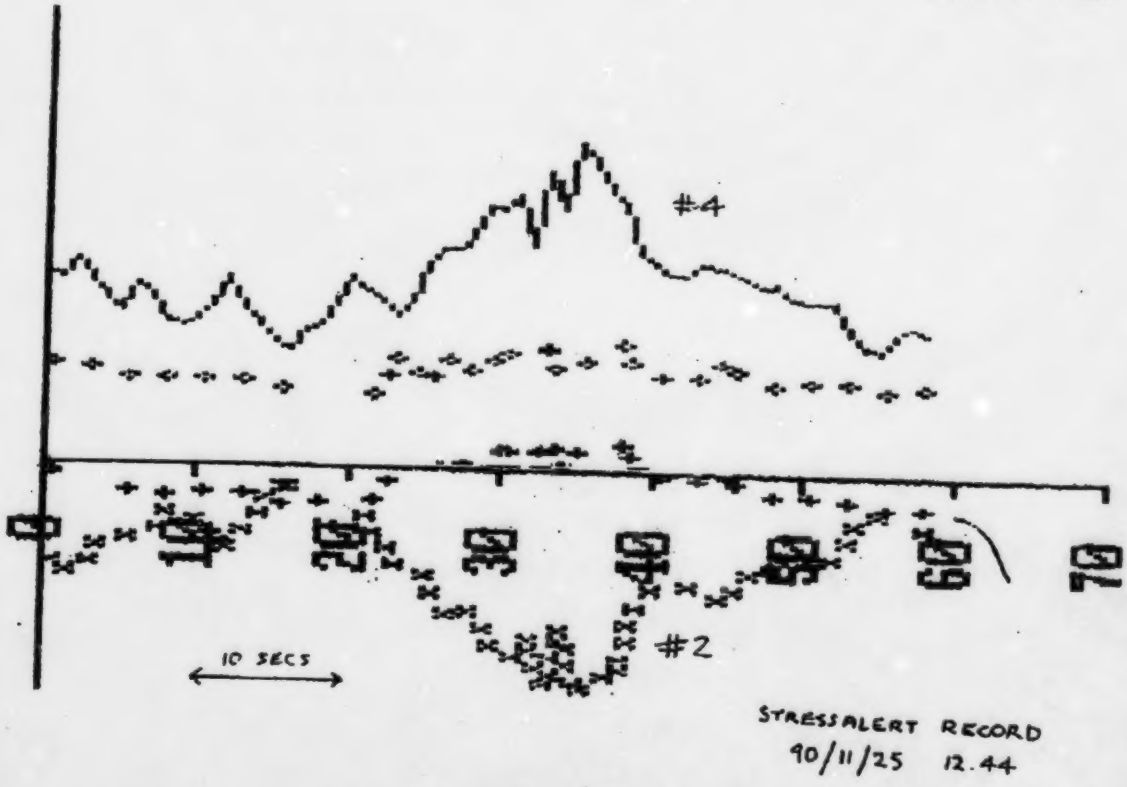


FIG. 3: COMPARISON OF CURRENT STRAIN RECORD AND PREVIOUS STRESSALERT RECORD

4. MAXIMUM AND MINIMUM STRESSES

THE FOLLOWING MAXIMUM AND MINIMUM STRESSES WERE RECORDED DURING THE 8 CYCLES CONSIDERED HERE:

CYCLE #	MAXIMUM OR MINIMUM STRESS GAUGE #2 (PSI)	GAUGE#4 (PSI)	OCCURRENCE IN CYCLE
1	-5800	7400	0.5S BEFORE END OF SWING TO DUMP
2	-6200	6800	0.5S BEFORE END OF SWING TO DUMP
3	-5000	5900	0.2S BEFORE END OF SWING TO DUMP
4	-5900	7300	0.5S AFTER END OF SWING TO DUMP
17	-6400	7400	0.3S BEFORE END OF DUMP CYCLE
18	-6300	7200	2.0S BEFORE END OF DUMP CYCLE
19	-7000	8200	0.4S BEFORE END OF DUMP CYCLE
20	-6300	7300	1.6S BEFORE END OF DUMP CYCLE

5. APPROXIMATE FATIGUE CALCULATION

AN APPROXIMATE CALCULATION OF FATIGUE LIFE OF THE TRI-STRUCTURE AREA IS POSSIBLE, BASED ON A TYPICAL STRESS HISTORY FOR A COMPLETE CYCLE, AS FOLLOWS:

GAUGE # 4 EXPERIENCES THE HIGHEST CYCLICAL STRESS OF THE 4 GAUGES MONITORED.

ONE DIG-SWING-DUMP-SWING CYCLE OF THE MARION 8200 CAUSES A STRESS CYCLE OF APPROXIMATELY 7400 PSI OR 51.0 MPA.

ASSUMING A WELD CLASS OF G FROM BRITISH STANDARD 5400, "STEEL, CONCRETE AND COMPOSITE BRIDGES. PART 10. CODE OF PRACTICE FOR FATIGUE, 1980", THE FATIGUE ENDURANCE CONFORMS TO THE FOLLOWING RELATIONSHIP AT A 50% PROBABILITY OF FAILURE:

NUMBER OF CYCLES TO FAILURE,

$$N = 10^7 \times \left(\frac{38.49}{\sigma_r}\right)^3$$

WHERE N IS THE NUMBER OF CYCLES TO FAILURE,
σ_r IS THE STRESS RANGE,
AND σ_r IS $\geq$ 38.49 MPA.

$$N = 10^7 \times \left(\frac{38.49}{51.0}\right)^3$$

$$= 4.3 \times 10^6 \quad \text{CYCLES.}$$

ASSUMING A CYCLE TIME OF 75 SECS, 7.5 HRS PER SHIFT, 20 SHIFTS PER WEEK, 51 WEEKS PER YEAR, THIS EQUATES TO AN APPROXIMATE LIFE OF:

$$\frac{4.3 \times 10^6}{\frac{7.5 \times 60 \times 60 \times 20 \times 51}{75}}$$

$$= 11.7 \text{ YEARS.}$$

NOTE: THIS CALCULATION ASSUMES A WELD CLASS OF G, WHICH IS AN CLASS GENERALLY ATTRIBUTABLE TO A POOR OR COMPLEX DESIGN OF WELDED JOINT. DETAILS OF THE JOINT DESIGN ARE REQUIRED TO MAKE A MORE INFORMED ESTIMATION OF JOINT CLASSIFICATION.

THIS CALCULATION ALSO IGNORES THE SMALL PERTURBATIONS ON THE MAIN STRESS CYCLE DUE FOR EXAMPLE TO JERKING OF THE BUCKET. HOWEVER THE INFLUENCE OF THESE WILL BE VERY SMALL AS THE NUMDER OF CYCLES TO FAILURE IS PROPORTIONAL TO THE CUBE OF THE STRESS RANGE.

6. CONCLUSIONS

ON THE BASIS OF THE STRAIN DATA SUPPLIED:

- WALKING AND DIGGING HAVE AN INSIGNIFICANT EFFECT ON STRESS AT THE LOCATIONS CONSIDERED ON THE TRI-STRUCTURE.

- THE HIGHEST STRESS OCCURS EITHER AT THE END OF THE SWING TO DUMP CYCLE, OR DURING THE DUMP CYCLE.

- IT IS LIKELY THAT MOST OF THE PREVIOUS STRESSALERT ALARM CONDITIONS RECORDED FOR THIS DRAGLINE HAVE OCCURRED IN THE VICINITY OF THE DUMP CYCLE.

J.V. DESLANDES

PRINCIPAL RESEARCH ENGINEER
BHP RESEARCH - MELBOURNE LABORATORIES

APPENDIX C.
DRAGLINE MONITORING AT N.B. COAL LTD.

DRAGLINE MONITORING

AT N.B. COAL LTD.

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Pre-Symposium Seminar No. 1,

Advances in Surface Mining Equipment Performance Monitoring,

(Draglines - Case Study 1)

Calgary, November 7, 1990

rpc

DRAGLINE MONITORING AT N.B. COAL LTD.

by

R. St-Laurent, Senior Engineer, Electronics Dept., Research and Productivity Council

J.V. Deslandes, Principal Research Officer, BHP Melbourne Research Laboratories, Australia (on secondment to Research and Productivity Council)

L. Danisch, Department Head, Electronics, Research and Productivity Council

I. INTRODUCTION

Our client, N.B. Coal at Minto, NB, uses a large Marion 8200-21R dragline equipped with a 65 cubic yard bucket for overburden removal to expose the coal seam. A dragline such as the Marion 8200 represents a significant capital investment and substantial operating costs. It is therefore very important to maximize machine performance and machine availability, as well as ensuring worker safety. In the past, despite the cost of the machine and its operating costs, there was little or no information available on machine performance. A Marion Programmable System for tightlining protection had been the only monitoring device fitted to this machine. Efficient and safe dragline operation was determined essentially on the basis of experience and manual control.

This paper describes a program subcontracted to the Research and Productivity Council (RPC) to improve dragline performance and safety through the use of computer monitoring and control. A four phase project is currently in progress. These phases cover the real-time monitoring of dragline structural stresses; the monitoring and control of dragline lubrication; the monitoring of dragline production and safety parameters; and the provision of a real-time operator and supervisor advisory expert system.

This paper describes the monitoring of operating stresses and the lubrication system of the Marion dragline at N.B. Coal.

II. MONITORING OF DRAGLINE STRUCTURAL STRESSES

Draglines used in coal mines are subjected to long term average stress from normal operation, as well as peak events due to mechanical malfunction or operator error. Because of the size of the structure, strain resulting in metal fatigue and subsequent fracture can be catastrophic in terms of safety to personnel and in terms of economic consequences due to downtime and repair costs. There are significant benefits to be gained by operating the machinery to its peak capacity without causing unplanned downtime.

N.B. Coal had previously experienced structural fatigue cracking problems on the tri-structure backleg kneeplate area of the Marion 8200 dragline, necessitating extensive repairs and substantial machine downtime. It was reckoned that real-time monitoring of stresses in the tri-structure area would allow a safe and efficient operating regime to be determined. This would occur by direct feedback of stress information to operators resulting from undesirable or unsafe operating practices.

Strain gauges were installed at thirteen locations to measure the stress regions at and near the kneeplate area -- refer to Figure 1 for the general location on the dragline. The strain gauge locations were established to determine maximum stresses in the kneeplate area: gauge locations were established following consultation with the Metallurgy Section at RPC and finite element analysis done at The University of New Brunswick. Four gauges were subsequently selected for continuous monitoring, shown in Figure 2.

A continuously running monitoring and alert system was then developed, installed and commissioned. Off-the-shelf hardware components were combined with custom software to monitor the stress at selected points. Figure 3 shows a block diagram of the "Stressalert" monitor and alarm system developed. The primary elements of the system are:

1) Strain gauge drivers.
2) Analog-to-digital conversion.
3) Microcomputer controller.
4) Non-volatile memory.
5) User interface.
6) Expansion "port" to connect with future system.

The system hardware is based around an IBM PC compatible laptop computer. In 18 months of constant use the only operating problem experienced has been the ingress of dust into the keyboard, which has now been prevented by installation of a clear form-fitting urethane compliant covering. Software was written in polyFORTH to meet the system requirements.

The general specifications of the RPC Stressalert are given in Table 1.

Figure 1: The Marion 8200 Dragline showing the location of the tri-structure backleg kneeplate.

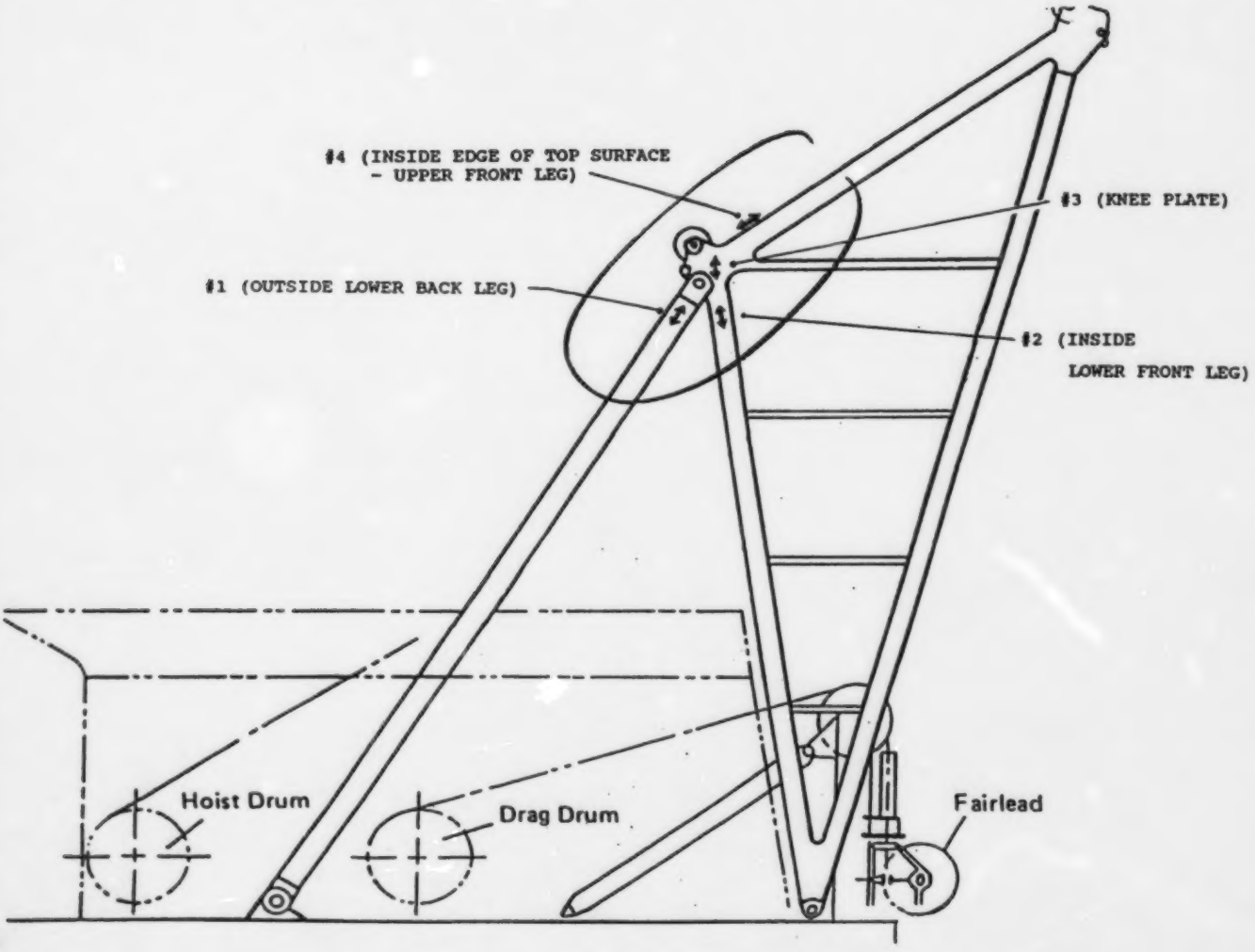

Figure 2: "Stressalert" strain gauge locations on the tri-structure.

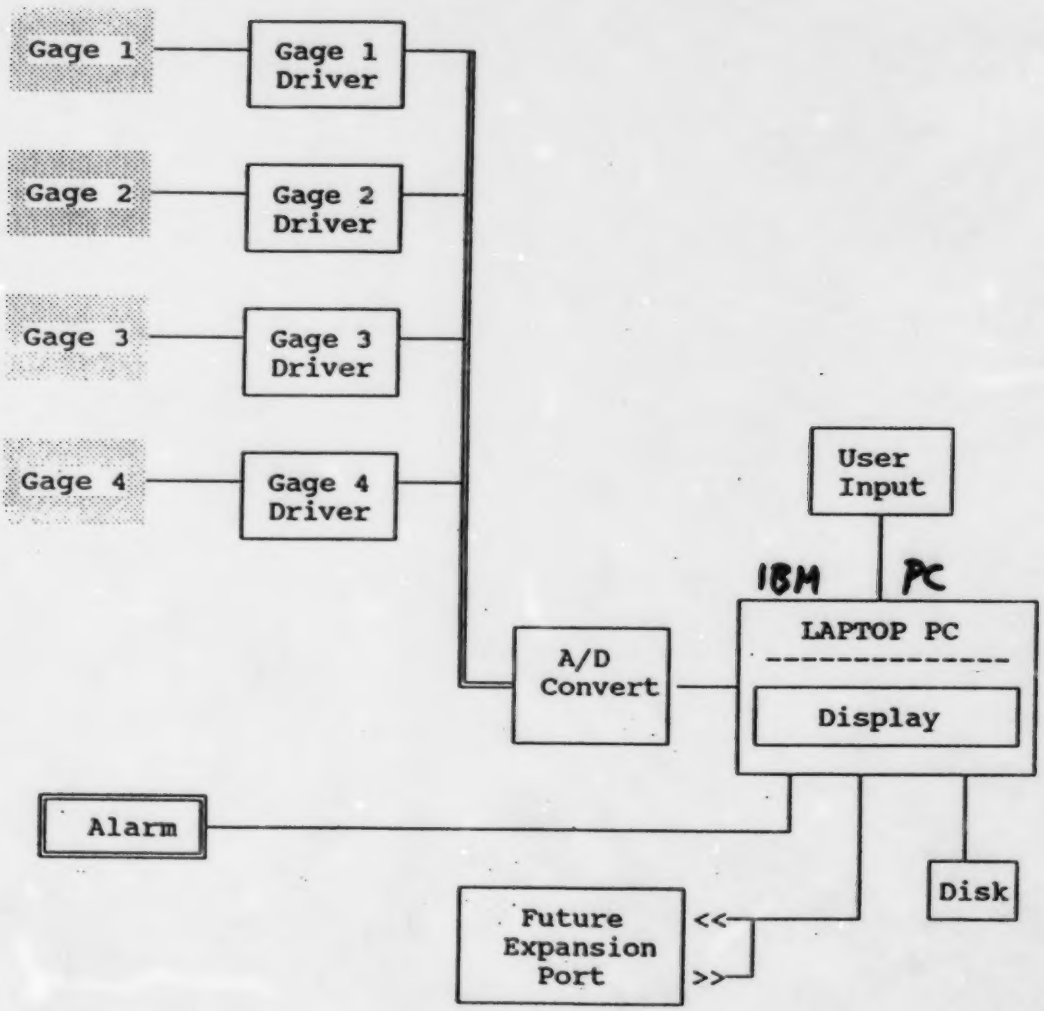

Figure 3: "Stressalert" Monitor/Alarm Block Diagram

Table 1

Specifications of RPC Stressalert

Size: The STRESSALERT consists of a robust, locked monitor unit 20 in. W x 30 in. H x 9 in. D; and a small alarm box that can be located close to the operator.

Event Graphs: All sensor data appears on graph, along with preset alarm limits. Graph from last event shows on monitor at push of button.

Sensors: 4 (expandable to 8). Other configurations available.

Operating Temperature: 5 to 35 deg. C. (41 to 95 deg. F).

Power Requirement: 110 to 120 VAC, 60 Hz, 1 Amp; other power configurations available. Data is protected against power outages.

Data Storage: 3.5 inch 720K diskette typically stores several months' records.

Event Recording: 4 stress values recorded every second, 40 seconds prior and 20 seconds after the event.

Routine Recording: Time stamp, and minimum and maximum stresses recorded over each hourly period.

Special Features: Write protection for AC outage, check of strain gauge calibration levels for unacceptable drift, easy change of stress limits by authorized personnel.

Recording Capabilities

The RPC Stressalert system provides the following capabilities:

(1) The maximum and minimum stress values encountered for each strain gauge over the preceding hour are recorded. Figure 4 shows an example of the routine hourly stress recording capability. The maximum (and minimum) stresses can be related to operator and digging conditions.

(2) Whenever the stress for any gauge exceeds preset limits, an audio-visual alarm alerts the operator, and the stress history is stored for the 40 seconds leading up to the alarm condition and for the 20 seconds following the condition. Figure 5 shows an example of the stresses recorded during an alarm situation. The stress in gauge #4 has exceeded the stress limit specified in the software. Stress preset limits are changeable by access to the keyboard, according to individual machine circumstances. A major feature of the Stressalert system is that the information can be displayed immediately on the screen in graphed form, so that the operator can view immediately the effect on machine operating stress of an undesirable operating practice.

Other features built into the system are a write protection against AC power outage, and a check of strain gauge calibration levels for unacceptable drift. The entire unit is housed in a sealed enclosure, with a simple two-button external control to allow untrained personnel to view event graphs and summaries of events.

The RPC Stressalert system has already been eagerly accepted by N.B. Coal's supervisory staff as a knowledge tool. The hourly stress ranges have been used to identify the operator and the nature of the overburden being excavated. The alarm events have been used to identify undesirable dragline operating practices, resulting in reductions in high stress events through training of operators.

```
Disk installed at 89/06/01 13:09                    Events=    8   Space left=  89%

89/06/02 08:00   1:   131  2784  2: -5363  2638  3:  -366   835  4: -1875  6917
More? (y/n) Y
89/06/02 09:00   1:   219  2960  2: -5715  2139  3:  -234  1040  4: -2095  7518
89/06/02 10:00   1:   -14  2887  2: -5598  2623  3:   -73  1025  4: -2154  7034
89/06/02 11:00   1:    29  2681  2: -5246  2799  3:  -205   908  4: -2491  6756
89/06/02 12:00   1:   161  2975  2: -6272  2212  3:    87  1348  4: -2212  7034
89/06/02 13:00   1:   102  2828  2: -5232  2960  3:  -146  1113  4: -2901  6946
89/06/02 14:00   1:   102  2681  2: -4763  2960  3:   -43  1099  4: -2535  6360
89/06/02 15:00   1:   -14  2491  2: -4601  2535  3:   146  1465  4: -2300  6184
89/06/02 16:00   1:  -102  2564  2: -4557  3033  3:   263  1480  4: -2051  5686
89/06/02 17:00   1:     0  2594  2: -4675  2755  3:   -14  1348  4: -2125  5701
89/06/02 18:00   1:   205  2681  2: -4250  3077  3:  -117   967  4: -1875  5759
89/06/02 19:00   1:   366  2725  2: -4132  2916  3:  -190   806  4: -1744  6082
89/06/02 20:00   1:   351  2769  2: -4264  2916  3:  -337   806  4: -1846  6199
89/06/02 21:00   1:   205  2975  2: -4704  3150  3:  -351   762  4: -1700  6697
89/06/02 22:00   1:   337  3048  2: -4440  2916  3:  -454   688  4: -1875  6301
89/06/02 23:00   1:   439  3092  2: -4587  3092  3:  -366   718  4: -1831  6741
89/06/02 24:00   1:   263  3238  2: -5041  3063  3:  -454   747  4: -1612  6873
89/06/03 01:00   1:   322  3165  2: -4953  2901  3:  -366   659  4: -1612  7181
89/06/03 02:00   1:   307  3253  2: -5334  3121  3:  -468   600  4: -2037  7210
89/06/03 03:00   1:   366  3238  2: -5525  2916  3:  -395   659  4: -1656  7181
89/06/03 04:00   1:   190  3165  2: -5334  2916  3:  -498   688  4: -2066  6976
More? (y/n)
```

Figure 4: Example of hourly maximum and minimum stress recording capability.

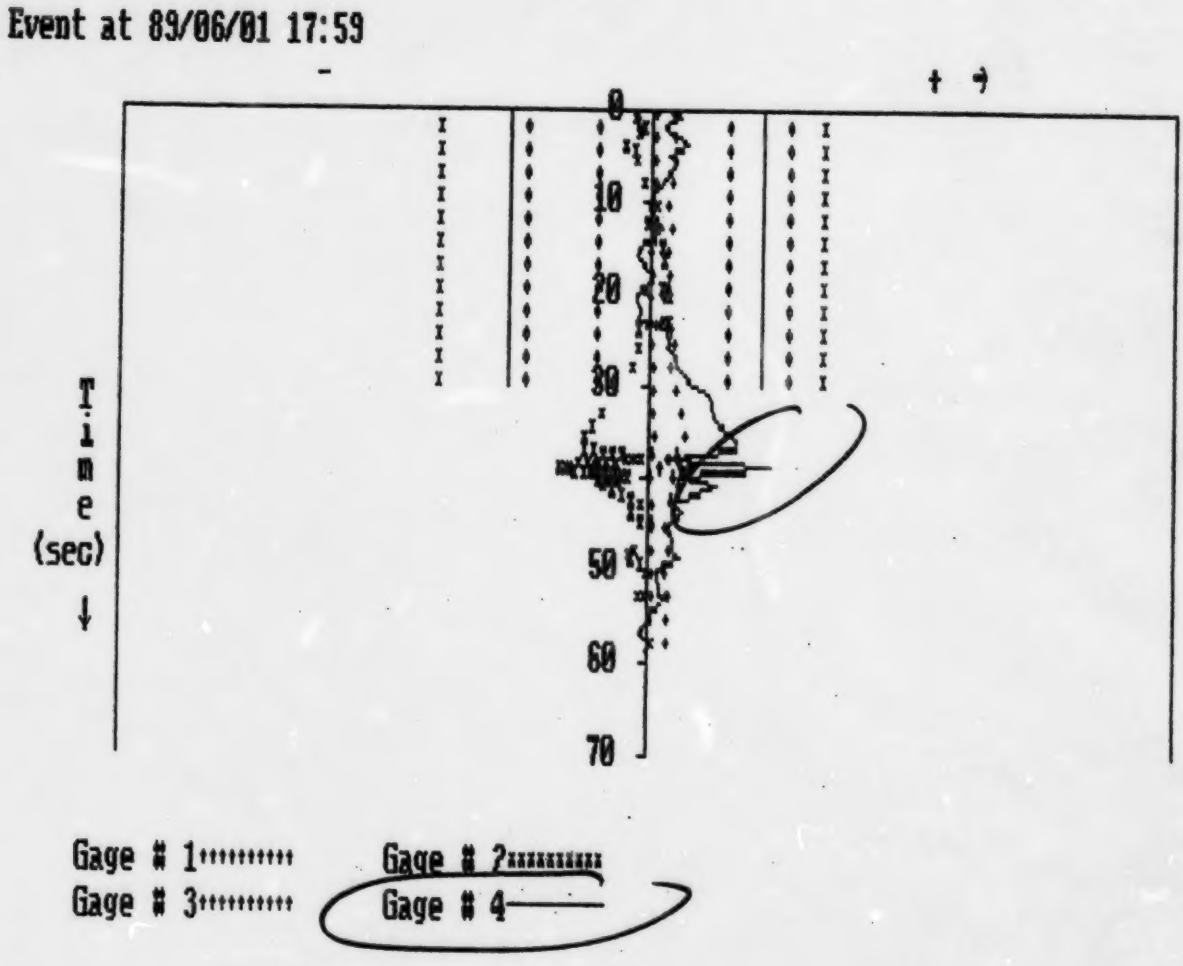

Figure 5: Example of stress event recording capability.

III. MONITORING AND CONTROL OF DRAGLINE LUBRICATION SYSTEM

Lubrication on a dragline is a severe and costly requirement. Insufficient lubrication can cause an immediate shutdown of the operation. Present N.B. Coal policy is to ensure there is an excess of lubrication, thereby sacrificing significant amounts of lubricant. With manual control of the lubrication system the only measure of use of lubricant is when the lube tanks are topped up every 3 to 6 months.

Apart from the obvious cost of the lubricant, overlubrication exacerbates a number of problems. The following have been recognized by Syncrude [1]:

(1) Overlubrication creates a housekeeping problem. Cleanup is also required before inspection and repairs.

(2) Solvents and lead added to common asphaltic type lubricants are an occupational health and safety problem.

(3) Cleanups are expensive in terms of machine downtime and man hours involved. Syncrude have estimated a cost of $90,000 for the cleanup process alone [1].

The present lubrication system is comprised of two main mechanized systems. A lube cycle is determined by electromechanical timers with manually positioned timing trigger tabs. A lube cycle for a piece of equipment is typically 30 minutes. The two systems serve the left and right side of the dragline separately.

RPC Computer Based Lubrication Monitor/Control System

RPC has developed and is currently trialling a computer based system to monitor and control the dragline lubrication system. The system was required to have the following capabilities:

1. Centralize the timing functions. Individual electromechanical timers would be replaced by software.

2. Measure the lubrication use on a level approaching the usage per cycle.

3. Monitor and record selected bearing temperatures. These data would be used to adjust the lubrication injectors to obtain the minimum flow that results in the optimal bearing operating temperatures.

4. Allow for expansion to add more individual temperature sensors.

A block diagram of the system is shown in Figure 6. Bearing temperatures are monitored by Omega Type K industrial grade thermocouples at 4 locations on the drag and hoist drum bearings; this is currently being expanded to 53 additional locations on the swing motors, drag transmissions, hoist transmissions, and motor-generator sets, as shown in Figure 7. A

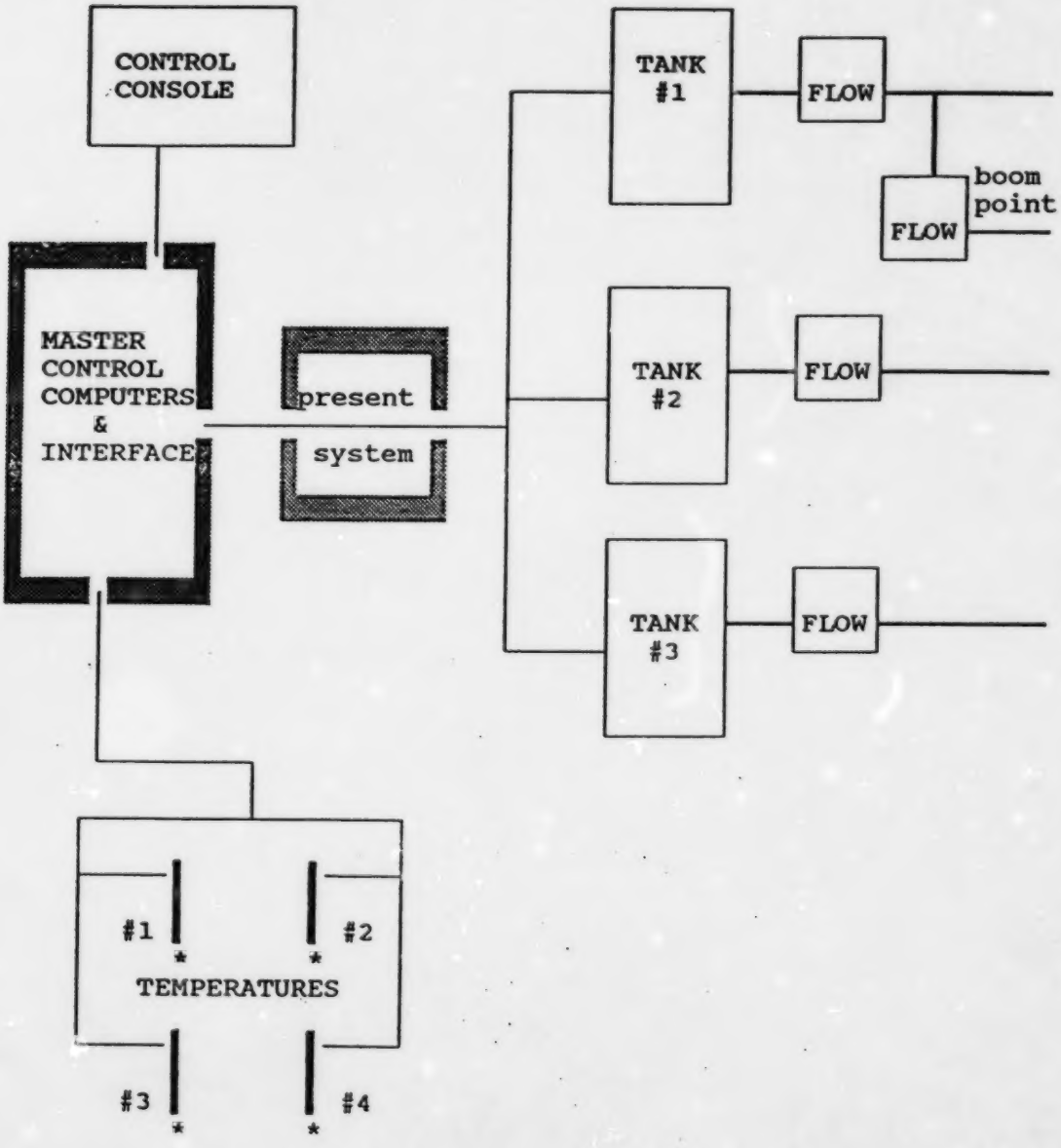

Figure 6: Block Diagram of Lubrication Monitor/Control System.

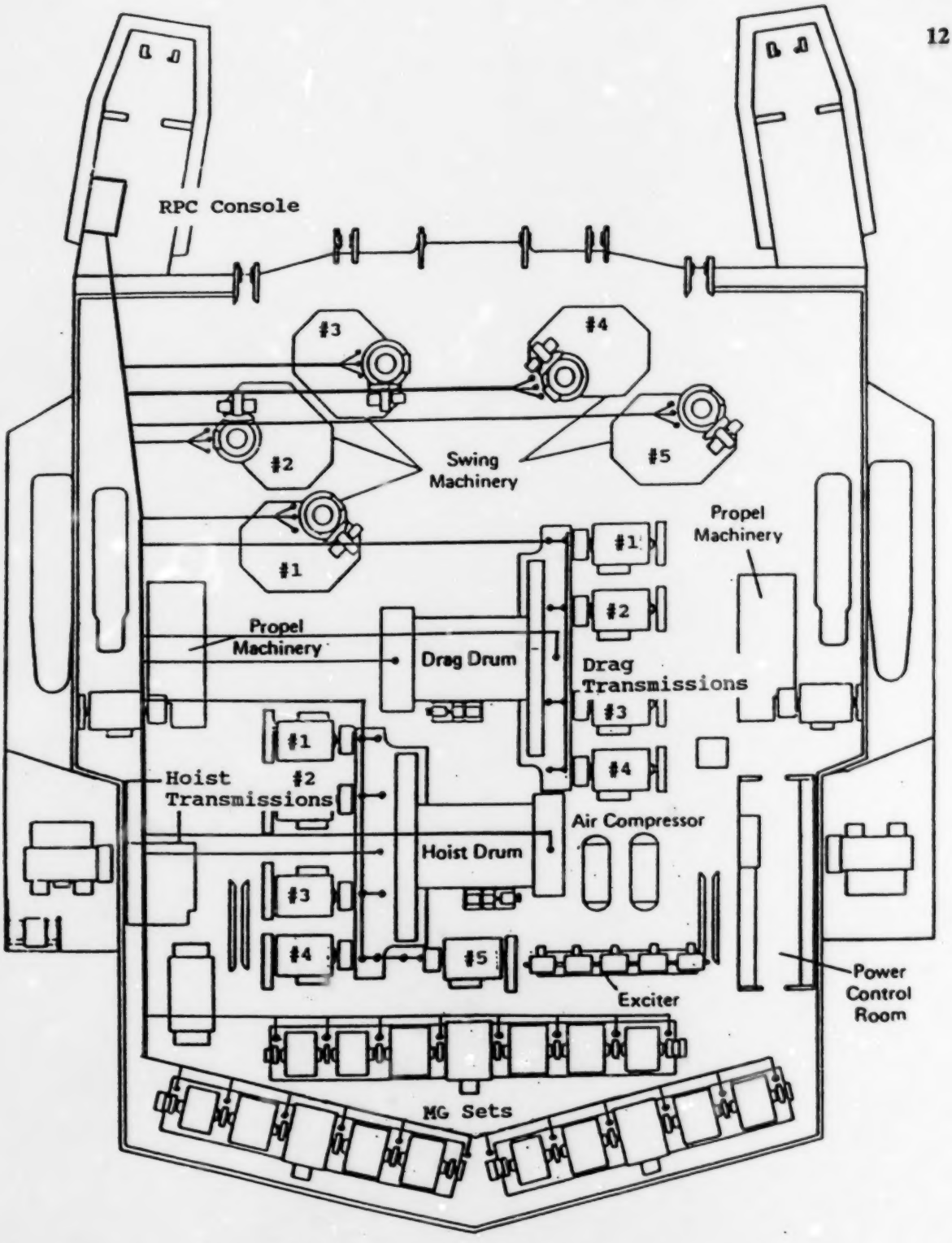

Figure 7: Thermocouple locations on Marion 8200 Dragline.

temperature rise can indicate the onset of bearing failure, allowing equipment to be shut down before serious damage results. Monitoring the bearing temperatures also allows the client to determine where reductions in lubrication can be made without affecting bearing operation.

A second area where lubricant reductions are expected to be possible is by basing the lubrication on actual machine operation rather than solely on time.

Lubricant flows are monitored by four ZHM series positive displacement gear flow transmitters. These units are bi-directional flow meters because there is substantial backflow into the lubrication tanks at the end of a lubrication cycle. Open gear lubricant is monitored by two of the flow meters - one meter being used to measure flow to the critical boom point lubrication injectors.

Levels of lubricant in each tank are monitored by sensing hydrostatic pressure in each tank.

Hardware is housed in a single six foot lockable enclosure, and is based on an RTX2000 data acquisition system from Innovative Integration. They have plug in peripheral analog and digital boards that are accessed via the RTX2000 ASIC bus. Each analog and digital signal line passes through an Analog Devices or Opto-22 module respectively for signal isolation. There is an RS232 link to the host. Software is written in modified polyFORTH. The RPC computer based lubrication has been designed to be failsafe - should the computer system fail then operation of the lubrication system automatically reverts to electromechanical control.

The computer monitoring and control of the Marion 8200 lubrication system is expected to allow a significant reduction in lubricant usage (with a corresponding reduction in lubricant cost and housekeeping problems), and allow the early detection of substandard bearing condition.

IV. CONCLUSIONS

RPC views the provision of real-time information on dragline performance as fundamental to improved mining machine performance and safety. Computer monitoring at N.B. Coal is expected to make significant advances towards the feedback of actual dragline performance to operators and supervisors alike.

V. ACKNOWLEDGEMENTS

The authors wish to acknowledge the support and co-operation of N.B. Coal Ltd., Minto, NB, and the Science Branch, Supply and Services Canada.

VI. REFERENCES

[1] Paton, Clifford G., Maciejewski, Waldemar B., and Melley, Roger E., "Test Methods For Open Gear Lubricants", Lubrication Engineering, May 1990, pp. 318-326.

APPENDIX D
DRAGLINE PERFORMANCE MONITORING AND CONTROL
AT N.B. COAL LTD.

rpc

DRAGLINE PERFORMANCE MONITORING AND CONTROL AT N.B. COAL LTD.

J.V. Deslandes

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Fredericton, New Brunswick

International Symposium on

Mine Planning and Equipment Selection in Surface Mining

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L. Danisch, Department Head, Electronics, Research and Productivity Council

I. INTRODUCTION

N.B. Coal Limited is located at Minto-Chipman, New Brunswick. N.B. Coal is a subsidiary of the New Brunswick Electric Power Commission, with the coal being supplied to the nearby Grand Lake Generating Station. Coal has been mined at this site since 1639, with current production at about 600,000 tons per annum.

Stripping is carried out with a Marion 8200-21R walking dragline, equipped with a 350 foot boom and 65 cubic yard bucket. The dragline is fitted with a Marion Programmable System for tightlining protection, but with no other monitoring devices as standard equipment. A dragline such as the Marion 8200 represents a significant capital investment and substantial operating costs. It is therefore very important to maximize machine performance and machine availability, as well as ensuring worker safety. In the past, despite the cost of the machine and its operating costs, there was little or no information available on machine performance. Efficient and safe dragline operation was determined essentially on the basis of experience and manual control.

This paper describes a program subcontracted to the Research and Productivity Council (RPC) to improve dragline performance and safety through the use of computer monitoring and control. A four phase project is currently in progress. These phases cover the real-time monitoring of dragline structural stresses; the monitoring and control of dragline lubrication; the monitoring of dragline production and safety parameters; and the provision of a real-time operator and supervisor advisory expert system.

It will be shown that the implementation of computer monitoring and control can lead to significant improvements to dragline performance and safety.

II. MONITORING OF DRAGLINE STRUCTURAL STRESSES

Draglines used in coal mines are subjected to long term average stress from normal operation, as well as peak events due to mechanical malfunction or operator error. Because of the size of the structure, strain resulting in metal fatigue and subsequent fracture can be catastrophic in terms of safety to personnel and in terms of economic consequences due to downtime and repair costs. There are significant benefits to be gained by operating the machinery to its peak capacity without causing unplanned downtime.

N.B. Coal had previously experienced structural fatigue cracking problems on the tri-structure backleg kneeplate area of the Marion 8200 dragline, necessitating extensive repairs and substantial machine downtime. It was reckoned that real-time monitoring of stresses in the tri-structure area would allow a safe and efficient operating regime to be determined. This would occur by direct feedback of stress information to operators resulting from undesirable or unsafe operating practices.

Strain gauges were installed at thirteen locations to measure the stress regions at and near the kneeplate area -- refer to Figure 1 for the general location on the dragline. The strain gauge locations were established to determine maximum stresses in the kneeplate area: gauge locations were established following consultation with the Metallurgy Section at RPC and finite element analysis done at The University of New Brunswick. Four gauges were subsequently selected for continuous monitoring.

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Figure 1: The Marion 8200 Dragline showing the location of the tri-structure backleg kneeplate.

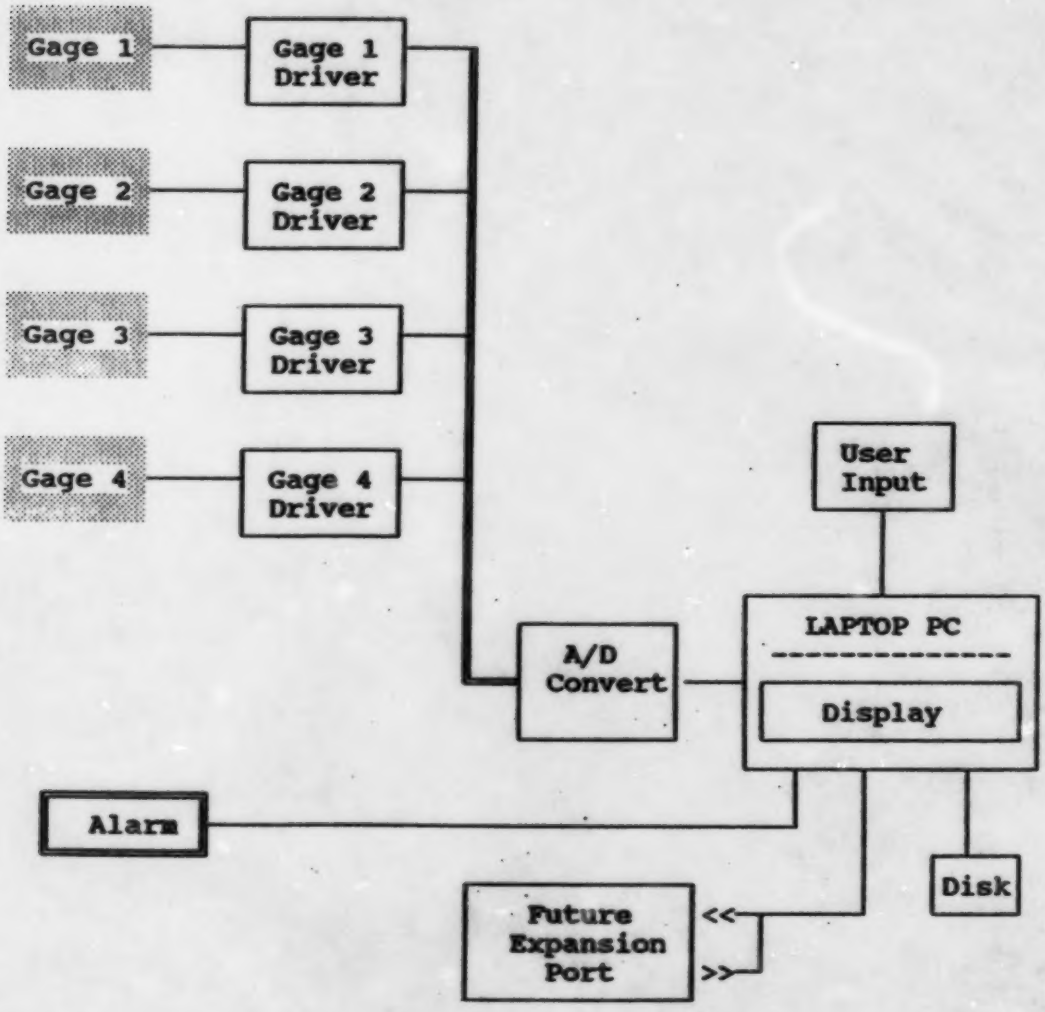

Figure 2: "Stressalert" Monitor/Alarm Block Diagram

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4. Allow for expansion to add more individual temperature sensors.

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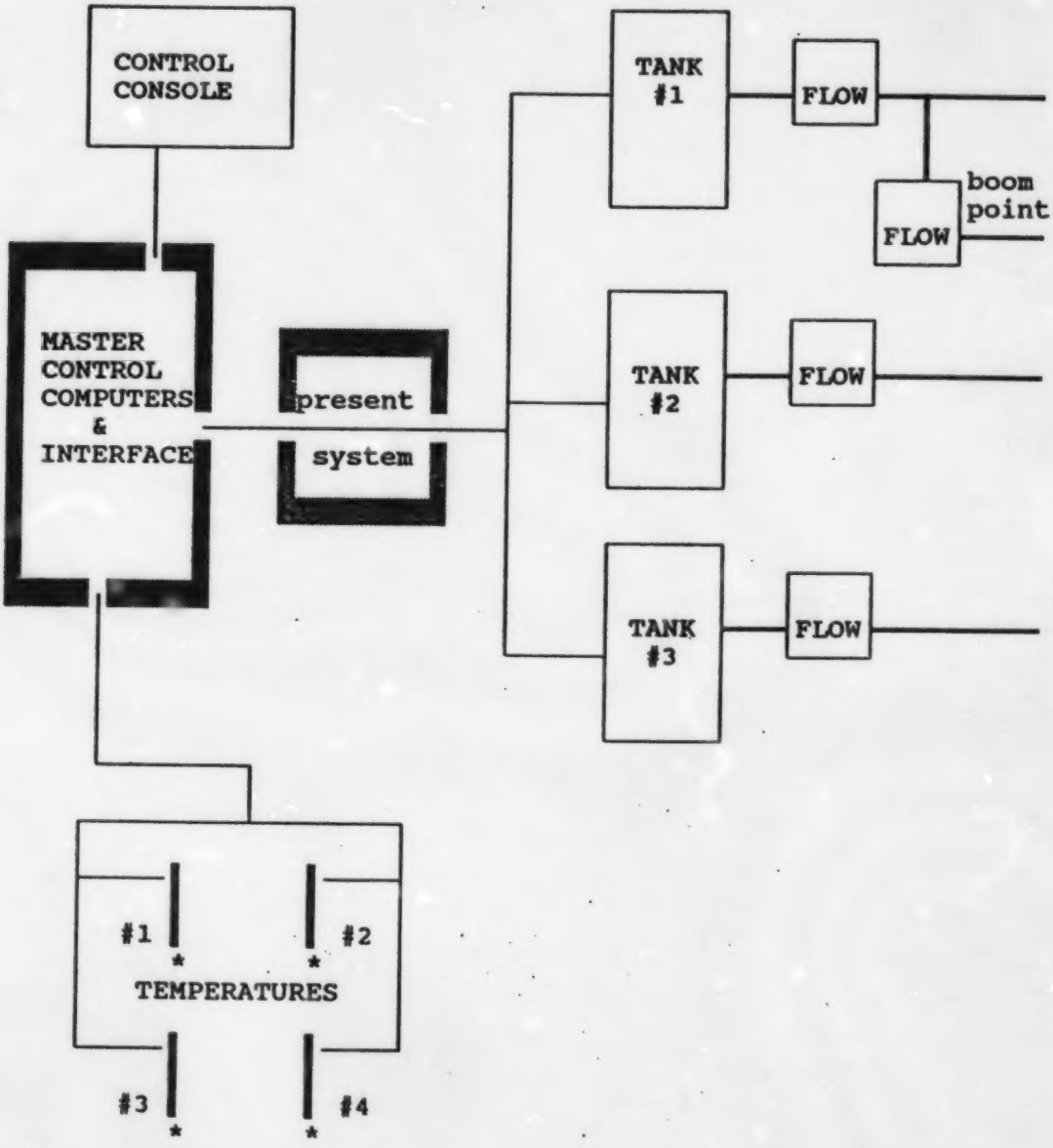

Figure 3: Block Diagram of Lubrication Monitor/Control System

measured by bi-directional flow meters because there is substantial backflow into the lubrication tanks at the end of a lubrication cycle. Tank levels are monitored by sensing hydrostatic pressure.

Hardware is housed in a single six foot lockable enclosure, and is based on an RTX2000 data acquisition system from Innovative Integration. They have plug in peripheral analog and digital boards that are accessed via the RTX2000 ASIC bus. Each analog and digital signal line passes through an Analog Devices or Opto-22 module respectively for signal isolation. There is an RS232 link to the host. Software is written in modified polyFORTH. The system is designed to be failsafe - if the computer system fails, then operation of the lubrication system automatically reverts to electromechanical control.

The computer monitoring and control of the Marion 8200 lubrication system is expected to allow a significant reduction in lubricant usage (with a corresponding reduction in lubricant cost and housekeeping problems), and allow the early detection of substandard bearing condition.

IV. MONITORING OF DRAGLINE PRODUCTION AND SAFETY PARAMETERS

In the third phase of the project which is currently underway, computer monitoring of pertinent production parameters is to be undertaken. The important parameters are:

- swing angle
- cycle time
- bucket load
- operational statistics

The **swing angle** will be recorded by using a potentiometer to measure the azimuth change for each dig-dump cycle. Currently this is recorded manually on a strip chart recorder.

Cycle time is obviously an important production parameter. This will be determined from the swing angle information, and automatically logged by the data acquisition system.

Bucket load varies with the nature of the material being excavated, and on bucket filling and spillage characteristics. Early attempts have usually been based on motor current and speed. These have met with mixed success, partly due to the fact that this is a very indirect method, far removed from the actual bucket dynamics.

We felt the bucket load could be isolated better by mounting strain gauge rosettes at the bucket cable attachment points. The stresses so determined could be used with the cable kinematics, also measured, to establish an algorithm for bucket dynamics and so infer the static bucket load. Strain gauges have been mounted on the boom point and on the fairlead pulley mounts for this purpose.

Operational statistics are presently recorded by the dragline operator on a sheet upon which he writes the time and a code whenever the overall state of the machine changes. The codes cover situations such as digging, walking (i.e. propel mode), lunch, and reasons for scheduled or unscheduled shutdowns. This function is to be integrated into the computer monitoring system. A transducer on the walking shoe will allow automatic logging of the number of walking cycles.

An important aspect of the third phase will be to interconnect the systems from the stress monitoring and lubrication control phases, and communicate all information to both the operator and to the supervisor. Operators will be able to enter dragline operating mode information at least as detailed as that now done on paper, which this can replace. The interface shall consist of an easy-to-use touch panel with menu driven, and perhaps graphics, displays on a backlit liquid crystal display panel. A separate interface will be provided to supervisors. This will allow examination of recorded data, changes to the control parameters, query system alarms and replace data diskettes. Access to this console is restricted to authorized personnel only.

The automatic logging of pertinent dragline production and safety parameters is expected to provide both management and operators with invaluable data on machine performance, hitherto not available on this dragline, as well as reducing the menial tasks required by the dragline operator.

V. REAL-TIME DRAGLINE ADVISORY SYSTEM

The first three phases of this project were used to establish a computerized system to acquire operation and safety related parameters on the dragline as well as to control the lubrication system. This phase, yet to be undertaken, is planned to produce a training and on-line monitoring system designed to improve the productivity of operators. Expert system techniques will be used to build a system that provides feedback to the operator in order to arrive at optimum performance within certain limits of safety. The feedback will include alarm warnings, information on present performance, and suggestions for improvements. The suggestions will be based on the performance of the best operators, as well as on theoretical operation curves.

There will be three locations of use:

1. **Operator's Console.** This will be a real-time display providing feedback to the operator on how performance can be improved while maintaining adequate operational safety margins.

2. **Supervisors' Console.** This provides complete access to the current and previous status of dragline parameters. Trends can be observed as well as accumulated results over a time period.

3. **Office Analysis Console.** Diskettes transfer data to the office computer. Detailed analysis and reporting will be available for all data gathered at the dragline.

OPERATOR'S CONSOLE

Expert system techniques will help us achieve a simple, useful interface. The operator will have a graphics display with a touchpad for data entry. We plan to use simple dynamically changing graphs to assist the operator to maximize performance without overstressing the dragline. The system will adapt automatically to changing overburden conditions; the operator will know when he should be more cautious and when he can push harder. The operator will have immediate feedback on how well he is performing. Overall shift results, such as digs per shift, may be obtained.

The operator will query the system to discover the cause of any warnings or alarms detected by the computer system. Touching the pad will identify the source of the problem so he can take the most appropriate action.

SUPERVISOR'S CONSOLE

This allows a supervisor to examine the status of any component of the system at any time. Recorded data may be examined to identify trends and to determine aggregate or averaged operating parameters, such as number of dig/dump cycles. Graphical presentation of parameters such as temperature over a time span will be available. The supervisor may also alter parameters such as alarm limits and lubrication cycle times.

OFFICE ANALYSES CONSOLE

This has all the capabilities of the supervisor's console except for the altering of parameters. Since it holds all the accumulated data, the office console can examine data over any time period. Printer report will be available. This feature can be used to generate weekly, monthly or annual reports. The users will be able to select which parameters are to be presented on the reports as well as their format of presentation. Options include graphical and tabular output. It will be possible to present data that is a function of more than one parameter such as:

1. Total bucket loads for an operator over a period of time.

2. All unscheduled downtimes that were electrical for an operator over a period of time.

3. Total lubrication usage in propel mode over a period of time.

In the development of a real-time dragline advisory system, the majority of the effort will be directed at developing the most beneficial human/machine interfaces for the three systems. Much effort will be expended interacting with N.B. Coal operations personnel to develop software that best meets their present and future needs.

VI. CONCLUSIONS

RPC views the provision of real-time information on dragline performance as fundamental to improved mining machine performance and safety. The computer monitoring and control system under development at N.B. Coal is expected to make significant advances towards the feedback of actual machine performance to operators and supervisors alike.

VII. ACKNOWLEDGEMENTS

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VIII. REFERENCES

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